# POWER SUPPLY CROWBAR CIRCUIT FOR PREVENTION OF THERMAL DESTRUCTION OF GaAs FET DEVICES

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## ABSTRACT

Thermal destruction of a GaAs FET can be prevented if excessive power dissipation can be prevented within the thermal time constant of the device. A circuit is presented which has been shown to be effective in protecting the MSC 88004 power FET in certain laboratory situations.

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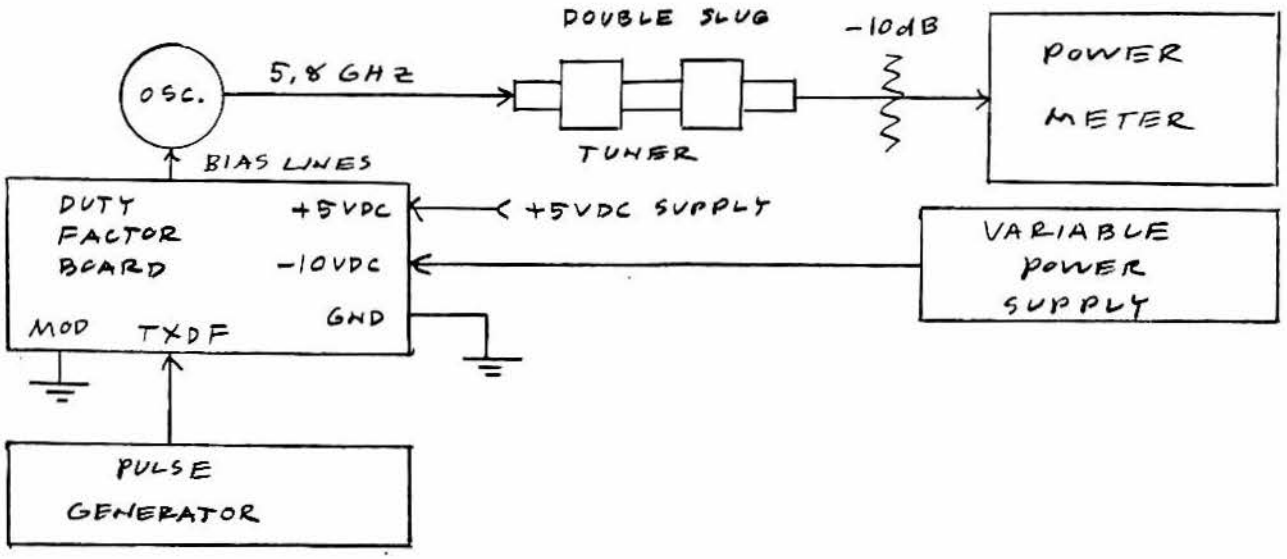
## I. Introduction

There are two common modes of destruction in power GaAs FET devices. The first is static voltage breakdown of the gate which is prevented by various grounding and static prevention schemes. The second is excessive power dissipation. The phenomena of power slump in pulsed GaAs FET oscillators provides insight useful for a protection circuit design.

Power slump limits the maximum R.F. output power of a pulsed GaAs FET oscillator. If the device is turned off well before its thermal time constant, considerably greater power can be obtained at higher drain to source voltages.1 This has been confirmed in experiments with an MSC 88004 C-band power oscillator. The oscillator had been matched for a maximum cw power output of 727 mW at 5.8 GHz. A double slug tuner was then placed at the output of the cw matching network to rematch the oscillator at various supply voltages in the pulsed mode. The test set-up and results are shown in Figure 1. The MSC 88004 reverse channel oscillator and duty factor board have been described previously.3 Since the oscillator was operated reverse channel with a source resistor for bias, the drain current should have remained approximately the same at various supply voltages. Note that the power almost doubled for a two to one increase in supply voltage.

TEST SET-UP




200 ns pulse width
20 µs repetition rate

Results

Pout cw @ -10 VDC = 727 mW peak
Pout pulsed @ -10 VDC = 869 mW peak
@ -15 VDC = 1.36 watts peak
@ -20 VDC = 1.58 watts peak

Figure 1

In his paper on pulsed GaAs FET operation, Wade measured the thermal time constant of the higher power MSC 88010 part at 15μs.1 Phil Wallace of MSC has stated that this should also apply to the MSC 88002 and MSC 88004 devices. It would seem logical that a protection circuit with a time constant of much less than 15μs could protect these devices in a cw environment from current transients, due to oscillation mode switching or output tuning.

## II. Crowbar Circuit

A schematic of a crowbar protection circuit used with reverse channel on GaAs FET oscillators is given in Figure 2. Since laboratory power supplies may have large values of capacitances at their output, the crowbar does not short the output of the supply, but instead opens the circuit between the supply and the GaAs FET circuit. This is accomplished through the pass transistor Darlington circuit. Use of a Darlington transistor minimizes the static power dissipation in the pass transistor, since its collector emitter voltage (which has to supply base current through the lamp) is minimized for the high gain available. This enables a smaller and therefore faster device to be used as the pass transistor.

An SCR which is used as the trigger device to cut off current to the pass transistor remains "on" until the input voltage is removed, a desirable feature in a protection circuit. It also has the advantage that its low "on" resistance is capable of switching the Darlington's input capacitance in a fast time. The threshold adjustment to the gate of the SCR is provided by a potentiometer at the output of a zener diode reference bias source.

Any abrupt change in output current caused by mode switching or tuning changes is coupled to the gate of the SCR through the transformer. A diode in series with the gate rectifies any low frequency oscillation that may occur with the GaAs FET circuit. Thus the SCR input capacitance will be charged by the rectifier and will fire when it's threshold voltage is surpassed. Otherwise, if the frequency of oscillation were high enough, individual pulses of regneration may not exist long enough to fire the SCR.

The bias potentiometer and series resistor comprise the reverse channel source resistance for the GaAs FET oscillator used here.

Note that this circuit has not been optimized and is not a rigouous design. Most of these components were readily available and were therefore put into service. Undoubtedly the speed of this circuit could be improved considerably for the currents used here.

## III. Evaluation

A photograph of the output voltage switching from -10 VDC to 0 VDC after triggering is provided in Figure 3.

# REVERSE CHANNEL POWER GAASFET OSCILLATOR POWER SUPPLY PROTECTION CIRCUIT

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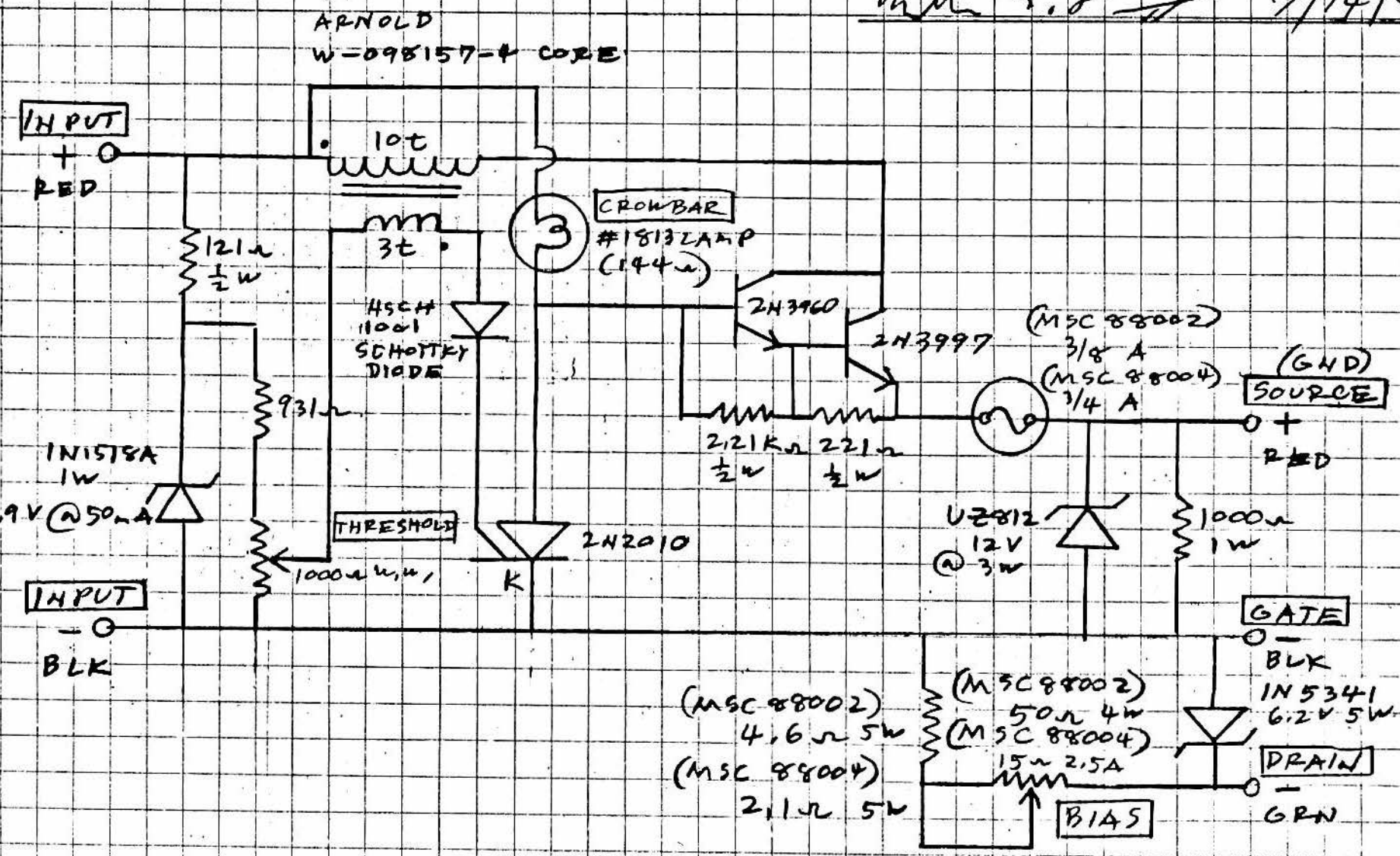
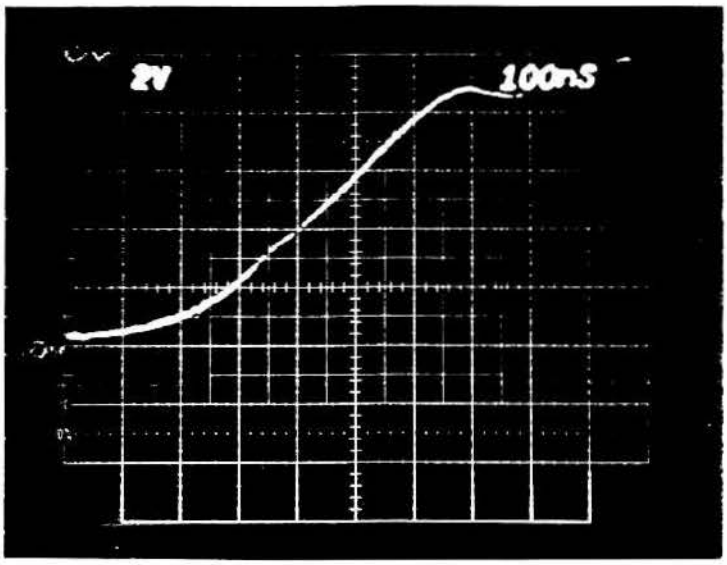



FIGURE 2

MSC 88002/88004
VDS (8 VDC)
VGS (2 VDC)




Protection Circuit Output Waveform when Triggered

Figure 3

In this particular case the load was provided by a 31.6 ohm resistor. The circuit was triggered by manually raising the threshold potentiometer voltage. The scope was triggered off of the output waveform. The 90% to 10% turn off time was measured at 0.65 μs, much less than the 15μs thermal time constant of the MSC 88002 and MSC 88004 GaAs FETS used here.

The circuit was shown to be effective in preventing damage to MSC 88004 power GaAs FETS, with multimoding. With an early MSC 88004 oscillator design which was prone to various modes of oscillation other than the one desired, the crowbar circuit triggered at a particular power supply voltage and thereby shut down. This could be repeated several times showing that the MSC 88004 had not been damaged. When the crowbar was defeated, the FET was destroyed.

Further examination with a new FET and the crowbar engaged showed a spurious noise cusp on a spectrum analyzer at an undesired frequency just rising out of the noise floor at a power supply voltage immediately below the trigger point. At the trigger point the crowbar would fire and shut down. Again if the crowbar was defeated, the power FET was destroyed when the power supply voltage reached the trigger point. This experiment was repeated a number of times with different FETS in the same circuit with the same result, and proved to be a valuable aid with experiments eventually leading to a solution of the multimoding problem. Similar experiments were conducted with an attempt to operate an Avantek part in a reverse channel oscillator.

Although detailed accounts cannot be given, the crowbar also appeared to protect power FETS during load-pull experiments.

## IV. Bibliography


1. Wade, P.C., Rutkowski, D., and Drukler, I., "Pulsed GaAs F.E.T. Operation for High Peak Output Powers", Electronics letters, 13th September 1979, Vol. 15, No. 19, pp. 591-593.

2. Conversations with Phil Wallace, Microwave Semiconductor Corporation, 1982.

3. "Aircraft Security Radar Development Report," Sandia National Laboratories, 1983.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